HISTORY OF WAKARUSA CREEK.

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WAKARUSA CREEK presents several peculiarities which attract attention. It is one of the few streams of Kansas which run due east throughout its course. It has a valley rivaling in width that of the Kansas. It shows in unusual degree the presence of red boulders from the north, and these have a peculiar distribution. Moreover, there are a few cases of so-called "stream piracy" and changes of channel.

The writer's attention was drawn to this stream because of its evident relations to the glacial deposits of the state, the study of which he has undertaken for the State Geological Survey, and it is with the permission of the director, Doctor Haworth, that this paper is presented at this time.

The writer's acquaintance with the subject has been much accelerated by information received from Doctor Haworth, Mr. Bennett and others of the Survey and by articles published by Messrs. Mudge and Hay, and particularly from the papers of Mr. Smythe, who published a map showing some of the more significant features.

The basin of the Wakarusa is about fifty miles long and from ten to fifteen miles wide. Its topography is quite varied, which is a natural result of erosion on its geological structure. The bedrock consists of several thin layers of limestone alternating with thick beds of shaly clay, including some not very extensive lenses of soft sandstone. All these dip slightly to the northwest. The larger streams have an easterly trend, or in an opposite direction to the dip. Conspicuous features, therefore, are several zigzag escarpments, the eastern edges of as many narrow rock-terraces, crossing the country in a north and northeasterly direction. Where these cross divides they make them considerably higher; where they cross streams their valleys are narrow and rocky. The principal one, and farthest east, is that of the Oread limestone. That of the Topeka limestone is less marked, while that of the Burlingame is more prominent and crosses only the headwaters. Below the last are the Scranton and Severy shales, 125 to 150 feet thick, which correspond to the low divide south and southeast of Topeka. Beneath the Oread are the Lawrence and LeRoy shales, 250 to 275 feet thick, which account for the great width of the lower part of the Wakarusa valley and its junction with the Kansas.

Following Ferrell's law, the streams of the basin have generally shifted to the south as they have cut down, so that the terraces are generally on the north and the abrupt bluffs are upon the south. The few changes of channels are toward the north, or down the dip.

TRACES OF DIFFERENT DRAINAGE LEVELS.

Evidences have been found of three or four different levels of drainage:

1. The highest and oldest noted is marked by stratified chert gravels several feet thick, capping the divide, five to seven miles south of Auburn. Their altitude is about 1200 feet.

2. The second consists of higher bouldery patches, showing a comparatively level surface of deposition either of streams or of land ice. This feature shows particularly south and somewhat north of the middle portion of the stream and of its valley about Clinton and eastward. These patches lie from 150 to 200 feet above the present streams.

3. In the eastern portion of its valley, limited and detached fragments of a lower level, more distinctly resembling a boulder-capped terrace, are found, 125 to 175 feet above the Wakarusa. The Three Sisters and a similar flat-topped hill east are the best examples.

Possibly these are but a lower continuation of the preceding, below rapids, by which the Wakarusa may have first crossed the Oread limestone. These are more clearly the result of stream action, and no boulder patches of the preceding kind are known as far east.

4. The clearest marked level may be called that of the lower bouldery terraces. It is marked by very impressive strips of red quartzite boulders from six inches to six feet in diameter. These strips are frequently entirely composed of boulders for a thickness of ten or twenty feet, and the depth of the bouldery deposit, including much sand and finer material, is sometimes forty or fifty feet. The upper portion, where it has not been subject to erosion, is frequently quite fine loam. Where erosion has been most active and the adjacent deposits soft, these strips stand out as ridges, which from their bouldery composition and linear form have been mistaken for moraines. This condition is perhaps best exhibited near Burnett's mound, southwest of Topeka. More frequently one side is eroded, with cross ravines revealing a cross-section of the old stream bed, with one bank remaining. Such is the case near Berryton, Tevis and Auburn. Sometimes the banks are traceable on both sides, as north of Pauline and southwest of Clinton.

The system marking this level consists of the main stream, following approximately the present Wakarusa, and three branches from the north, viz.: The Auburn branch, which came over from Mission creek by a col. east of Dover, and down the present North branch, past Auburn; the Pauline, or Lynn creek, branch, which came over from Shunganunga creek, east of Burnett's mound, ran south and southeast a little north of Pauline, and then divided, part continuing southeast and the other turning more east, past Berryton and Tevis; the Stull branch, which came over the divide north of that place and followed the present course of Deer creek. The summit of these deposits is about 100 feet above the present streams toward the west, and less than eighty feet toward the mouth of the Wakarusa. From U. S. topographic maps and barometer readings, the following altitudes have been calculated: Col. east of Dover, 1050 A. T.; top of terrace near Auburn, 1100; top of ridge east of Burnett's mound, about 1050; top of alluvium covering channel, north of Pauline, 1030; the same southwest of Clinton, 950. At the latter place a good cross-section of the old filled trough is shown, by a more recent diversion of the stream to the north. It is about forty feet deep and one-third of a mile wide. The lower Oread limestone forms its bottom and the upper Oread the banks on either side.

5. Lower terraces are locally developed, and the present stream is twenty-five to thirty feet below the present narrow flood plain.

DISCUSSION OF THESE FEATURES.

A study of these features promises to be more satisfactory if we begin with the simpler first. This will be the direct reverse of chronological order. The lower terraces are easily understood and comparatively unimportant.

1. The lower bouldery terrace, from structure and position, shows clear evidences of having been formed when the ice sheet was close at hand. The flowing of copious streams over the divide between the Wakarusa and the Kansas shows conclusively that the valley of the latter was effectually blocked in some way, doubtless by the marginal portion of the great ice sheet of the so-called Kansan epoch of the glacial period. The excavation of the channels was evidently done by the water from the ice. The Auburn branch was probably an outlet from a glacial lake in the Mission creek valley, the Pauline branch one from a similar lake in the Shunganunga valley, and the Stull branch probably came directly from the edge of the ice. The second was the largest and longest occupied. In other words, they might be considered "valley trains"

from the ice front. The boulders accumulated as the strength of the current declined from the subsiding of the waters from some cause, either by diminution of the rate of melting or the diversion of the flood down the Kansas valley from the melting back of the ice front. That temporary floods still occupied the older channel from time to time is inferred from the deep silt capping overlying the gravel and boulders.

2. The problems furnished by the bouldery patches and the higher bouldery terraces are much more complex and difficult. We think best to treat them separately, though there are reasons for thinking them possibly contemporaneous. The bouldery patches are a mere veneering of boulders over elevated points not quite up to the general upland level. There is not enough of clay or gravel associated with them to show whether they are the deposit of land ice or of shallow streams or irregular lakes. It seems that they may be arranged into channel-like strips, but the patches are so detached that the appearance may be illusive. Four possible explanations present themselves: First, that they are the work of a pre-Kansan ice sheet. Second, the work of a more advanced stage of the Kansan sheet, postulating that that sheet lingered long enough afterward to erode channels 100 feet deep and to fill them as contemplated under the head already considered. Third, they may be the work of shallow streams wandering over the plain in front of the Kansan sheet before Wakarusa valley had been begun. A fourth view may be that that they are the deposits of a temporary glacial lake formed in the valley of a small tributary of the Kansas, which may have flowed northward along the line of Coon and Oakley creeks, and which was dammed by the advent of the ice sheet.

In favor of the first supposition, it may be urged that traces of such an advance of the ice have been found as near as southwestern Iowa, and that it would easily afford adequate time for the erosion of such a valley as we have found in existence during the Kansan stage in the terrace already discussed. Against such a conclusion, however, is the apparent impossibility of conceiving an ice sheet covering these areas south and southeast of Clinton, without leaving traces of its presence over wide areas where no trace is found. For example, no traces are found on the higher points of the divide north of the Wakarusa from north of Stull eastward, and no traces south of the Wakarusa on this level west of Rock creek.

In favor of the second theory, the size of some of the boulders, viz., five to six feet in diameter, would be some evidence of glacier action, rather than water, but the objection so strong against the former view would be quite as cogent here. Besides, the difficulty of conceiving the Kansan stage to linger long enough to erode a deep valley and partially fill it again is quite serious.

The third view harmonizes well with the possible arrangement of the patches in channel-like lines, with their being on lower levels than others near by which are bare of drift, and it also evades easily the difficulty of the patches being so far from other clear traces of glacial occupation. But it does not avoid the great erosion demanded during the Kansan ice stage. Some will find serious difficulty in accounting for transportation of such large and so many boulders by water. This may be obviated, however, by remembering the efficiency of river ice. Anchor ice may have been more efficient at that time, also, and ice blocks from the glacier front may have assisted.

The fourth explanation is favored by all that favors the last, and it reduces indefinitely the demand for so long a time for erosion during the Kansan stage, for there would be in this case only need for the cutting down of narrow divides under favorable conditions. Another difference would be that it conceives the distribution of boulders by lake ice more than by river ice, though both are involved more or less in each explanation. The conception is that instead of the single valley of the Wakarusa, there were two or three tributaries running northeast into the Kansas between Topeka and Eudora. The Oread limestone formed the divide between the eastern one and the one next west, which, as has been already stated, probably followed the line of Rock, Coon and Oakley creeks northward. There may have been another divide corresponding to the Topeka limestone crossing the valley somewhere near Richland. According to this view the coming of the ice blocked the lower courses of these tributaries, changing the one west of the Oread divide into a lake, in which for some time ice blocks from the glacier front floated, distributing boulders. Eventually the waters rose and broke over the divide eastward. The fall was at first considerable, for the stream then occupying the present lower course of the Wakarusa was not obstructed, but ran on the preglacial level of the Kansas, which was only about 100 feet above the present stream. The Three Sisters and other boulder-capped hills east were probably portions of the old channel of that time.

3. The stratified chert gravels were indefinitely older and of

streams of uncertain direction. Little time has been spent on them. They may be of Cretaceous time, the work of a stream flowing into the Cretaceous sea a little farther west; or, more likely, they may have marked the eastward course of a Tertiary stream, a pioneer of the present eastward drainage, flowing across the divide before the Kansas had swung into its present course, and long before it had excavated its present valley.

SKETCH OF THE HISTORY OF WAKARUSA CREEK.

Putting the foregoing conclusions into chronological order, we may sum up as follows:

Following or attending the elevation of the Rocky Mountains, at the end of Cretaceous time, the great plains became dry land and sloped more and more toward the east. As a result, rivers began flowing in that direction, possibly, though not certainly, outlining something like the present Missouri system. There is considerable evidence that at first they ended in playa lakes and that there was much aggradation and building up of alluvial plains. Eventually they made their way through to the line of the Missouri or its predecessor, and the chert gravels may have been formed about that time, before valleys had been deepened to any great extent.

During the Tertiary there was first deposition and building up of the Great Plains, but later erosion lowered the principal valleys till, at the beginning of the Pleistocene, or at least when the ice sheet arrived, they were about 100 feet higher than at present. This is attested by remnants of preglacial gravels near St. Marys and Topeka, and other marks of its position near Manhattan and St George.

It is probable, as already suggested, that two or three short tributaries of the Kansas flowed northward across and along the present course of the Wakarusa. The eastern one may have headed west of Vinland and followed approximately the course of the Wakarusa eastward. The second may have headed in Rock creek valley, received waters from Camp creek and Deer creek from the west, and flowed along the line of Coon and Oakley creeks to the Kansas. This theory has not been tested in the field. The drainage of the area west of the Topeka limestone may have also gone northward independently, or it may have joined the stream just sketched.

DURING THE PRESENCE OF THE ICE SHEET.

The ice, gradually approaching from the north, doubtless swelled the streams receiving its water, and increased their erosion and the coarseness of their deposits. In fact, the gravels marking

the preglacial channel have some northern pebbles mingled with the upper portion of the prevalent chert pebbles from the west. Eventually the ice reached the Kansas valley and soon filled it from near Lake View to Wamego. West of the latter point was formed a large lake, first recognized by Robert Hay twenty years ago, and named later by Mr. Smythe "Kaw lake." There were probably several other smaller lakes in various tributaries of the river, one of them being, as we have suggested, in the valley of Rock creek. It should be remembered that the whole western edge of the ice sheet from Montana south must have had its drainage turned first into the Kansas, and at the stage now considered, diverted over into and along the present valley of the Wakarusa. The result was that one after another the valleys became lakes and overflowed the divides, at first by very winding, irregular and shallow courses, scattering boulders, in some cases pushed along by the current of the stream, but frequently by river ice or by blocks from the glacier itself. To such conditions we are disposed to refer the highest bouldery patches south of the Middle Wakarusa. Soon the water began flowing over the Oread limestone into the easternmost valley and began to form the bouldery channel of which the Three Sisters are the more notable remnant. For a time, doubtless, quite a cataract existed a little west, as the Lawrence shales were cut out by the falling water, and the Oread was cut through rapidly. One effect of such a situation would be that the stream would frequently shift because the shale would cut away more rapidly than the bouldery bed of the stream. The course was cut back over the old channel south of Clinton, as already indicated.

The front of the ice sheet was meanwhile looking over the divide at several points, and streams past Stull, Pauline and Auburn were at their prime and rapidly eroding, for the slope was steep for such large streams. It might perhaps be supposed that most of the peripheral stream would have come over at Dover, but judging from the deposits, the Pauline branch was the largest and longest occupied. Before the ice had receded much, the streams had cut down to the level of this lower bouldery terrace. At that time the Wakarusa still flowed south of Clinton, and Deer creek did not join it till several miles further east. The latter stream, not having to cut down through the Oread so deeply—perhaps because it had taken advantage of the previous erosion of the preglacial stream, or, more likely, from some other advantage of direction of joints or softness of rock, or possibly because of the northern dip of the rocks or the

more rapid filling of the channel of the other with drift—had cut lower than the Wakarusa a few miles south. The seepage from the latter, down the dip and in the direction of main joints, conspired to the final result. A branch from Deer creek finally captured the Wakarusa west of Clinton and diverted it northward past Belvoir along the course it has since followed. This may have been about the time the ice began to recede, but it cannot be stated with definiteness.

SINCE THE DEPARTURE OF THE ICE SHEET.

The Wakarusa was at its greatest development when the ice was at its prime. When warmer days forced the ice to recede, very soon the waters which had been forced over the divide south began again to follow the larger valley of the Kansas, as they had done before. This left the Wakarusa again to its own resources alone, to rainfall only. Erosion, therefore, was much slower. The level of its mouth, however, was still lowered by the cutting down of the Kansas valley. This for some time—*i. e.*, until the ice had receded perhaps to the mouth of the Platte river in Nebraska, at least until it had reached the Nemaha—must have been the main channel of the master stream of the western plains as well as of the west edge of the ice sheet. To this influence we ascribe the main part of the erosion of the lower hundred feet of the Kansas and of the Missouri below their junction.

As the "base level" of the Wakarusa was lowered, in this way, that stream cut out also its lower hundred feet, and at the same time shifted southward. This accounts for the general absence of northern drift south of the stream, even at low levels. Any erratics which may once have rested there have been undermined, rolled into the stream and buried or carried away.

This finishes our main story, but there is an appendix which may appropriately be added. As the Wakarusa was lowered with the Kansas, so were its other tributaries, including the Shunganunga. As that was lowered, erosion was very active east of Burnett's mound around the head of the Pauline branch, or "valley train." The shales were rapidly cut down, while the bouldery contents of the old channel resisted. Ere long a valley appeared on either side of the old channel, and each rapidly cut back southward, assisted by numerous springs in the shales. At length the eastern one cut considerably deeper, and then began seepage through the coarse gravel of the channel from the western channel to the eastern, with the result that a tributary of the latter tapped the western one and stole its headwaters. This interesting case of "piracy" may be seen two or three miles northwest of Pauline.